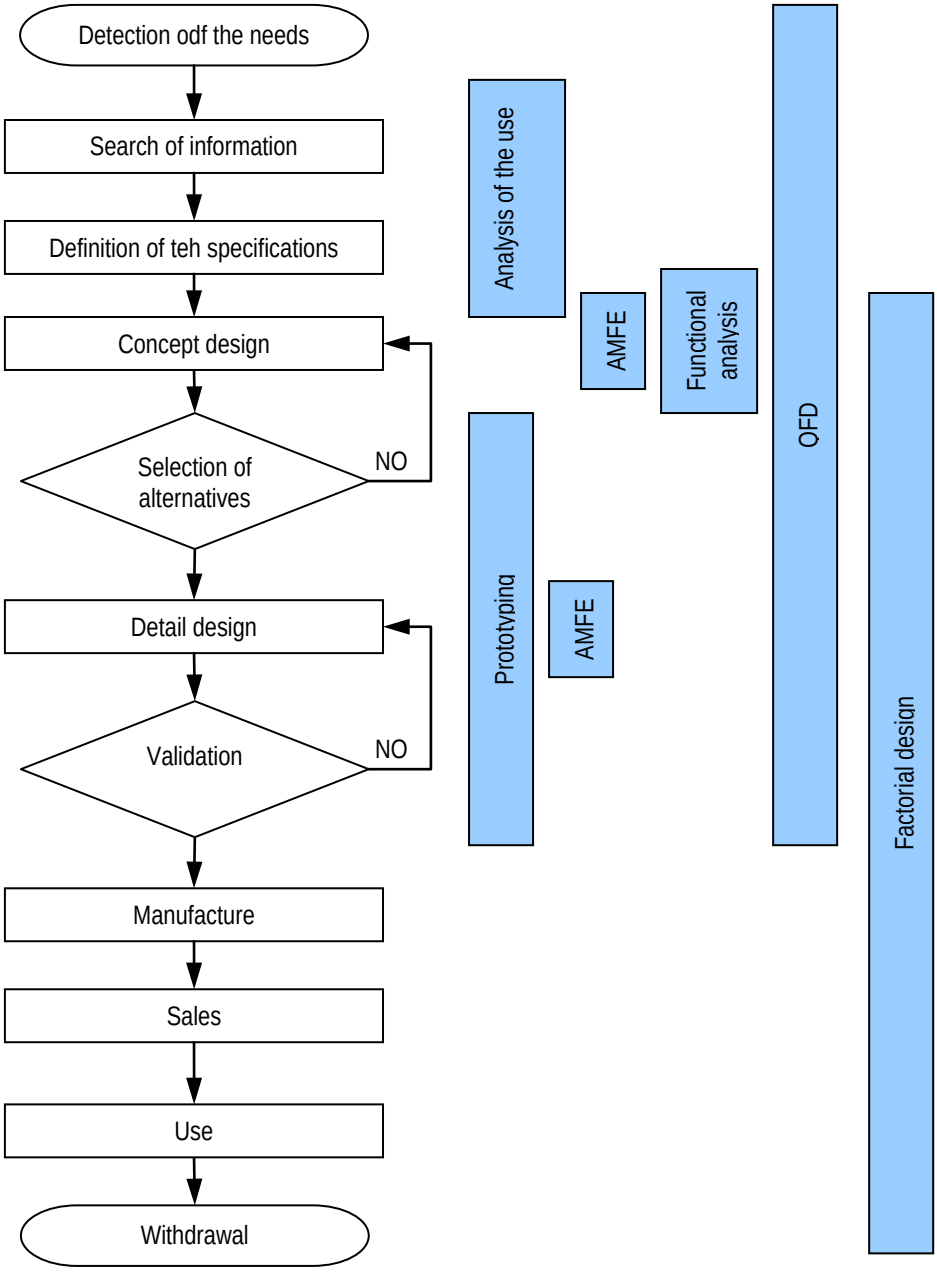
3. Industrial design and product development

In 1995, Reich defined the design as "a process in which the required function is defined and restrictions are specified and as consequence, the process describes a tool that fulfils the functions and restrictions specified".

Pahl et al. (1995) propose a systemathic approach to the theory of the design. The model of the proosed process of design is described as follows: planification of the desing of the product, conceptual desing, design of the assembly and detail design.

- Planification of the design of the product: gathering information about the product requirements and creating the first ideas of the product are the main tasks of this phase. The result of this working phase should be a full list of all the requirements.
- Phase of the conceptual design: an abstraction excesice is carried out in order to detect the basic problem. In this phase, the fuctional working structure is stablished, the working steps are specified and by combining both, the main solution is defined.
- Embodiment design (phase of the design of the assembly): the working plan is carried out taking into account the technological and economical requirements. The system created in this phase enables the testing of the functionality, the strength, the spacial compatibility and so on. By the end of this phase it should be possible to evaluate the economical viavility of the product.
- Phase of the detail design: in this phase the technical drawings are defined and described.

In order to clarify each working phase described above, a flow diagrama is shown below in Image 3.1. Most of the desing techniques shown in the diagrame are applied by computer systems.



3.1. Image. Phases of the design process. Development of the product and the most commonly used techniques.

3.1. Conceptual desing

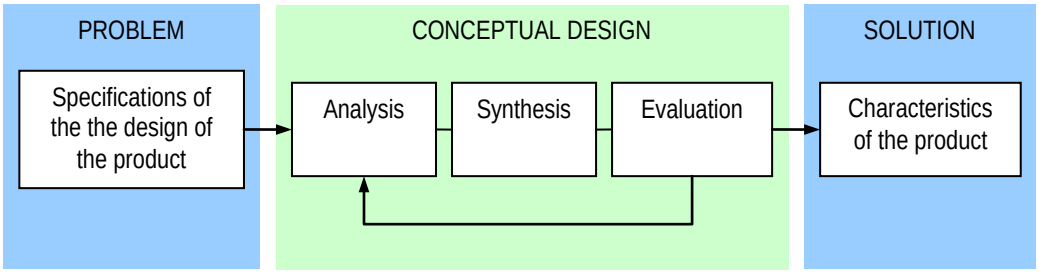
An ideal profile of the product is obtained where all the aspects related with the product are known and analysed. Then, the characteristics that fulfil the profile are pursued.

The conceptual design involves:

- Abstraction exercise to detect the basic problems.
- Determination of the functional structures.
- Determination of the working steps.
- Combination of the working steps with the functional structure.

- Development of the main solution.

In this phase, the problems presented due to the specifications have to be solved. A general model of the product that fulfils all the functions is presented.



3.2. Image. Phases of the cenceptual design.

Overall, ideas and solutions are the main elements of this phase

3.5.1. Solutions

Once the idea for the design is clear enough, the team begins the search for possible solutions. In practice, as the specifications are being detected and determined, many ideas may come to our minds. It is very important to write dawn all these ideas and keep them for the posterior phases instead of developing them at the moment. The development of an idea in the wrong phase can easily lead to uncorrect or poor solutions.

The quality of the solutions is the starting point to create solutions. Do not create a single solution, it is dangerous to design a product based in only in one solution. The single solution may hinder the creation of new solutions. For this phase, creativity exercises are helpful.

Conceptual solutions are designed in a general way. In fact, the morphology and the general functions of the product are taken into account. However, the limit between a conceptual design and a detail designed is not obvious. Depending on the specific case of design, the conceptual design may require more or less details.

The most important decisions are taken during the first steps of the design of the product: functionality, quality, manufacturing and costs. Therefore, these first steps are critc in the design process.

All the ideas generated from the conceptual design must define the product, including the sub systems, their functions, general morphology and general solutions for novel technical characteristics.

"Design for a particular purpose" is a technique that pursues the optimization of a product where the cicle of life of the product is accurately described.

3.5.2. Communication of the ideas in the conceptual phase

During the conceptual design, the team mates have to use all the sources to search for solutions. In this regard, part of the work will be to express and share the own ideas with the rest of the team mates.

In the first stages of the product development, usually the work is done hand written in paper. However, thanks to electronic and computing advances, the development of virtual prototypes is easy and quick. The prototypes enable the visualization of the sketches as well as the volume and the morphology.

Nevertheless, a designer must control the drawing of sketches. Sketches can be quickly perfomed and easily modified. They are part of the initial phase and informal phases of the design. In addition, it is easier to express ideas by means of sketches illustrated in sheets, therefore, the communication of inmature ideas is always done using sketches.

The skethes drawn in during this stage are not likely to the illustrations of the final product. These sketches are part of the internal documents for the design. The main characteristics of the sketches are the following:

- Although sketches are proportional to the product under design, they do not have a precise scale.
- Additional comments of the designer are usually required in order to understand the sketches.
- Sketches are used to carry out formal and ergonomic analysis and to study the different possiblities to locate the elements that form the final product.

In general, conceptual sketches are use during the conceptual design phase as a tool to analyse all the possible alternatives.

3.5.3. Analysis and selection of the solutions

For a correct evaluation of all the ideas, in first place, the evaluation criteria need to be defined. For the definition of the criteria the specifications of the product are taken into account (functionality, weight, volume, confort, handeling, maintenance...) and then, each criterion is weighted.

In the evaluation process the viability of the product is analysed from differet points of view.In this step aspects that can be quantified and the ones that can not be quantified have to be separated. Aspects that can not be quantified are difficult to include in mathematical models, however, virtual models are very helpful for the clarification of all those unquantifiable aspects.

3.2. Detail design

Once the conceptual design is performed and the team-mates have the solutions to fulfil the specifications, the phase of the detail design begins. The limit between the two phases is not very clear, depending on the product under design it can vary.In general the detail design is related to the design of the components that integrates the final product.

Every product is formed by different components. These components are not completely defined in the previous phase. In fact, the components can also be modified during the detail design due to the manifacture, materials that need to be used or the morphology, among other factors.

The 70-80% of the design activity of the industry belongs to the detail design. These activity is not effective if the the rest of the work performed in the previous stages is not carried out following the methodology correctly.

In the detail design, materials, techniques for the analysis and novel technologies are included. The designer will include all these aspects not only in the physical properties but also in the functional ones.

The design performed during this phase has to include the precise design of every component that integrates the product according to the specifications defined in the conceptual design. In the detail design the product is considered as a global product, therefore every component required to fulfil the funcitonality must be defined and developed during this phase.

At this moment, a pure detail design is carried out. Indeed, dimensions of all the components enabling a correct operation of the assembly and the required calculations are specified. The complexity of the process depends on the complexity of the product under desing. CAD systems are hepful for the modelling, the movement of each componets, existence of interferences between components or the resoponse of each component to a certain load ca be modelled.

Thye final technical drawings of the product are the result of this desing phase. The documents available by the end of this phase should be the following:

- Technical drawing of the assembly.
- Explotion of the assembly. It is not necessary to dimension it, however notes explaining the montage of the assembly can be added.
- Individual technical drawing of each component. The dimensioning and the manufacturing specification must be included.
- The analysis carried out during this phase. Every calculation performed during the design processes must be collected in a document. This document will be available any time required.

3.3. Validation

Traditionally the validation of a design was carried put by making a prototype of the assembly using clays, mud, plasticine, etc. A prototype is a mere model of the final product obtained by different manufacturing processes. Prototypes are used to check the correct functionality of the designed product.

Before making the prototype, the design must fulfil certain conditions:

1. It should resemble the final product as much as possible according to the manufacturing processes. However, the process can be switch for this purpose because few, even a single prototype is made.
2. It should resemble the final product as much as possible according to the morphology and functionality. The aim is to extrapolate the results obtained from the prototype to the real and final product. Once the design is validated, the production phase begins.

"Quick prototyping" is defined as: group of tools to manufacture pieces based on CAD data or scale models.

Quick prototyping is useful to visualize the product throughout different stages of the design. This prototyping method reduces the time required for the development and enables the early detection of defects. Some times the models generated with quick prototyping are considered and used as final pieces.

3.4. Manufacture

The design and development of a product requires a manufacture system. By means of modelling simulation techniques, the final product and manufacture processes are designed and modelized.

CAD systems offer modelling and simulation options which are useful due to their capability to predict the characteristics of the product and as consequence the optimum selection for each situation.

Different models are used in the area of Engineering Projects:

- Coceptual models. Flow diagrams, circuit diagrams, qualitative graphics and block diagrams among others are included. The aim is to improve the knowledge of the specifications of the object that has to be modelled. The problems are reduced; the components and the relationships among them are defined and are all included into a block diagram.
- Grafical model. The specifications and drawings of the assembly are represented in the diedric system, perspective, electronic model, kinematic diagram, graphical calculations and ergonomics. The aim is to represent the elements developed during the conceptual design by expressing the relationships among them and functionality by graphical language.
- Physical models. This type of models includes aesthetic prototypes to analyse the assembly visually, its aerodynamic behavior and resistance, models of instalations and chemical instalations. Indeed, models for the analysis of the assembly and the interferences are included. Physical, geometrical and organization principles are used to create these models.
- Mathematical models. Continuous models generated with differential equations, dynamic and kinematic analysis of the mechanisms for instance, discrete system models, etc. Using continuous and discrete models the analysis of the manufacture is carried out. The aim is the representation of the elements and their relationships by means of the mathematical language. This model is completed when an equation system that enables the analysis of the behavior of the product to different stimuli defined.

The evaluation of the model is done performing different trials and tests. Thus, it is possible to evaluate the distinct hypothesis.

When the model is useful to answer any question about the object it can be concluded that a model can represent an object

3.3. Image: The self-personal model in a modelling process.

The main goal of a simulation is to evaluate the functionality and behavior of the real system.

The simulation can be useful in many situations:

a. There is no mathematical expression for the system under study, or its resolution is very complicated and the analitical models required for such purpose are not available.

b. The existing models and methods are very complicated to be used, therefore the use of simulations simplifies the work.
c. There is little information about the system.
d. Legal or ethic reasons prohibit testings.
e. Before creating the system, its behavior needs to be analised.
f. Information of a slowly developing system is required. Simulations reduce the time scale.
g. Simulation enables the study of systems in real time.

Regarding the manufacture, there are several tools vailable in the market to do digital manufacture. Fabrication lines can be analised in the digital manufacture and ergonomic, production, time etc simulations can also be performed. Thye dinamic representation of a graphic model makes possible all these options described above.

It is also possible the generation of a model of the final product using realistic techniques and to make its simulation. Thanks to the virtual models, by using a small amount of prototypes, the design of the product can be validated.

Besides all the advantages mentioned for the simulations, there are some drawbacks which are listed bellow:

- The definition of a model for simulation is very comlex and therefore time consuming.
- Often many simplications are applied to generate the models, which turns into confusing o erroneous results of the simulations.
- The lack of precission of the simulations is difficult to estimate.

3.5. Documents of the product

The development of a product requires four documents: memory, specification document, budget and technical drawings. In this section these documents are briefly described.

3.5.1. Memory

The description of all the aspects of the product are included in this document: characteristic, manufacture, materials, background, analysis of the market, etc.

3.5.2. Specification document

This is the document that is used by the design team. In short, it is the contract between the design group and the person that purchases the product. In this document the cooperation conditions are defined as well as the product specifications defined by the promoter.

The desig team analyses this documet to validate the legal requirements and the specifications of the product stablished by the promoter. These specifications will define the direction of the project.

3.5.3. Technical drawings

The design group makes these documents. Final technical drawigs are made once the design and the product are validated. This document is a key document for the manufacture, hence they have to be developed very carefully (Purcell et al., 1998).

Any technical drawing of a product has the same aim: to communicate the concepts of the product defined by the design group to the head of a manufacturing process. In this regard, the technical drawing has to be clear and have to describe the whole product.

The technical drawing of the assembly is the reference technical drawing of the product. In such drawing all the components that form the assembly are visualized and a reference to the technical drawing of each of the components is done. Thus, from the drawing of the assembly, it can be easily found the technical drawing of any component.

The technical drawing of a subset includes all the components that integrate the subset. The subset can be mounted independently to the assembly. In general, it is shown as an exploded drawing and a reference to the technical drawing of each component, the number of components and some dimensions are included.

The characteristics of the techical drawing of an assembly or a subset are the following:

Technical drawings of an assembly	Technical drawings of a subset
- The full product is expressed. - The organization of the products is expressed. - Explanations to carry out the assembly are some times included. - General dimensions of the product are included. - A numbered list of the components and subsets is included. - Specifications can also be added.	- A full subset is expressed. - The organization of the elements is expressed. - Explanations to carry out the assembly are included. - General dimensions of the subset are included. - A list of the elements is included and the technical drawings or the catalog is referenced. - Specifications for the assembling and construction are added.

3.1. Table: Characteristics of the technical drawings of the assemblies and subsets.

Technical drawings of the pieces or elements are the drawings of each element that belong to the assembly. These drawings include all the specifications of each piece, geometrical characteristics, tolerances, materials, superficial finishes, etc for its manufacture. The main characteristics of this type of technical drawings are the following:

- A full piece is expressed.
- Dimensions, tolerances, superficial finishes are included if required.
- Materials and manufacture processes are also included.
- References to other technical drawings can also be added.

3.6. Presentation

The presentation of the project is not a part of the project itself because it is not considered to be necesary to fully define the product, nor to implement it. In general it provides an added value to the project where the manufactured product is presented. It can be used as a commercial presentation.

The main goal is to present the final product. The characteristics of the product are atractively presented using animations or illustrative pictures. This type of documentation is usually presented in fairs.

A presentation can inlcude:

- Images in perspective of the model.
- Coloured projections.
- Eye-catching or innovative specifications.
- Representative images of the functionality.
- Advertising images.
- Computer based simulations of the model.

3.7. Bibliography of the industrial design and product development

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